

Radiation Physics Note #19

QUALITY FACTOR MEASUREMENTS AT FERMILAB USING A RECOMBINATION CHAMBER

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One of the factors involved in determining the biological effect of ionizing radiation is the "quality" of the radiation. There is evidence that this quality dependence is primarily caused by the difference in rates of energy loss (dE/dX or LET~~•~~) along the path of charged particles in the particular medium of interest. Since dE/dX depends on the velocity of the charged particle (as well as its charge and mass) there will be a distribution of energy loss along the trace due to the particle slowing down. Hence, a radiation field will have a particular dE/dX spectrum in a biological material and this spectrum along with the overall intensity will determine the biological effect of the radiation. A quantity called the quality factor (QF) has been defined for radiation protection purposes, and the QF is an administrative approximation giving the relative effectiveness of radiation to cause biological damage for a given amount of energy absorbed by a biological material. The QF has been related to dE/dX and the relation is generally given in a tabular form.

Hence, we see that QF determination involves in some manner measuring the dE/dX spectrum and weighing this according to the table defining the QF. In most cases in real life, the result of this complicated procedure may be approximated

by the QF pertaining to the average dE/dX . The REM-2 ionization chamber determines an effective QF by using recombination methods, i.e., the effect of the dE/dX of a particle on the process of columnar ion recombination.

Quality factor determination is made by measuring the current at two different voltages. One voltage (1200V) is well into the saturation region and the other voltage (65V) is in a region where there is appreciable columnar recombination. These voltages, the size of the chamber, and the pressure of the gas have been chosen such that the QF is a simple algebraic function of the ratio of the two currents. However, it has been found (in situations where time is not pressing) that a useful practice to follow is to take a set of points spanning the entire voltage range from 1200V to 3V. Comparing this curve to calibration curves, taken with a γ source and with a neutron source (Fig. 1), gives one a better feel of what is occurring.

Calibration runs were taken under different conditions (time after turn-on of high voltage, source distance, type of source) as summarized in Table I.

Field measurements were made at various locations at Fermilab. In some cases, plateau curves were taken and at other places only a QF measurement was made. These measurements are summarized in Table II. It should be noted that Fig. 6 of this note is taken from Radiation Physics Note #11 which gives more details about the E100 labyrinth measurements. The errors given are the usually \pm 25% given in the technical write up of the device; however, it should be noted that in some cases, the dose rate was so low or the normalization measurements so poorly taken that the errors are larger. The last attachment is the operational guide that has been developed for using the REM-2 device in the field.

This report has summarized a series of field determinations of the "quality factor" at various locations at Fermilab. These measurements represent the first physical measurements of this quantity at Fermilab and it is a tribute to the competence of the people who designed the radiation monitoring system (and/or the reasonableness of nature) that the instruments have a built in quality factor of 5. This factor of 5 agrees quite well with the quality factor determinations made near hadron loss points.

I gratefully acknowledge the loan of the instrument from S. Pszona, Institute of Nuclear Research, Swierk, Poland, and I would also like to thank P. Ruffin and R. Meadowcroft for their help in setting up and calibrating the instrument.

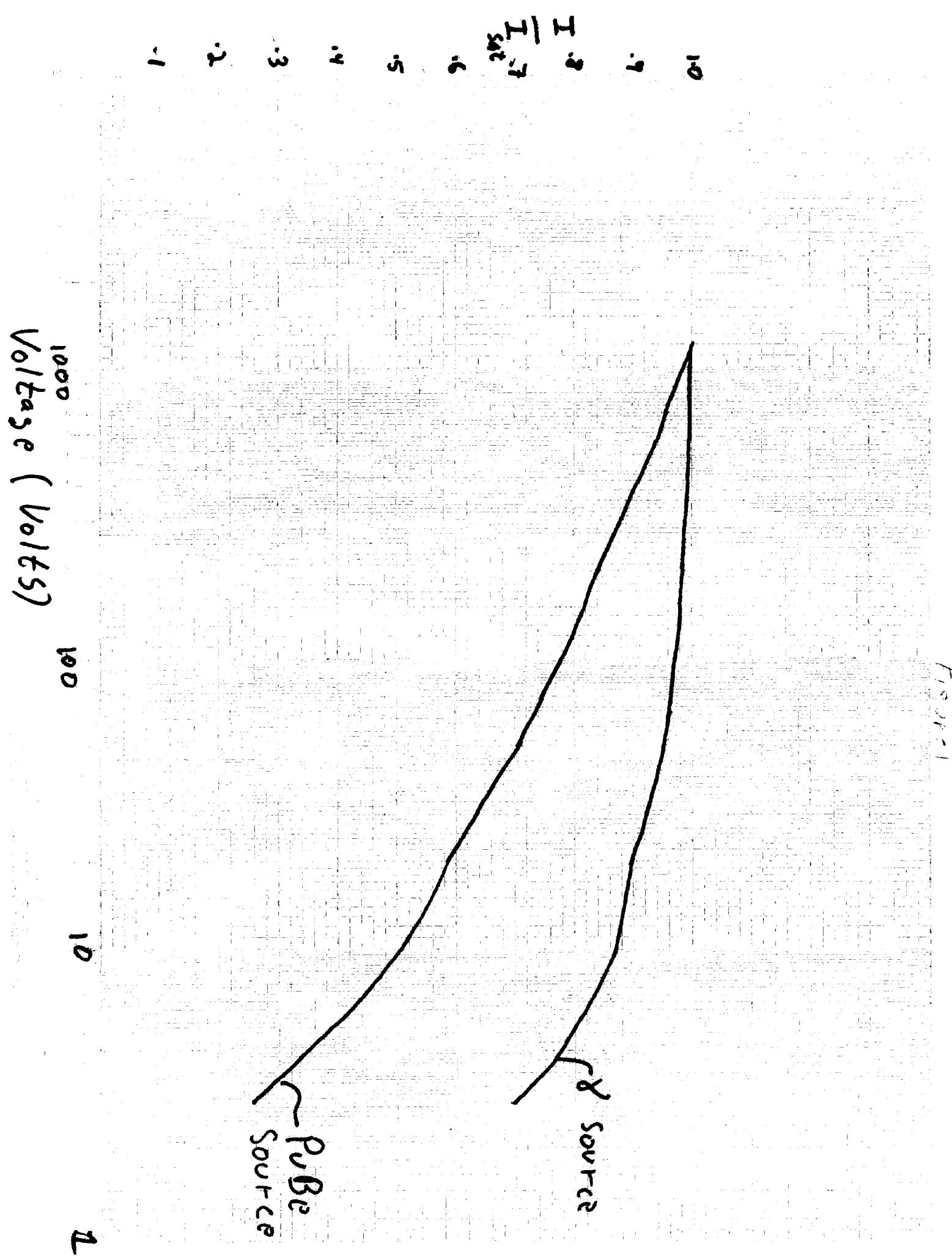
TABLE I

<u>CURVE</u>	<u>TIME OF FIRST MEASUREMENT</u>	<u>SOURCE (ATTENUATOR)</u>	<u>DISTANCE</u>
High Voltage On	10:45		
Fig. I	10:51	Cs 8.1 (x10)	174 cm
Fig. II	11:06	PuBe	40 cm
Fig. III	11:50	8.1 (x10)	174 cm
Fig. IV	12:00	PuBe	40 cm
Fig. V		8.1 (x800)	174 cm
Fig. VI		PuBe	46 cm
Fig. VII		PuLi	40 cm
Fig. VIII		8.1 (x1000)	110.9 cm
Fig. IX		8.1 (x1000)	192 cm
Fig. X		8.1 (x10)	174 cm
Fig. XI		PuBe	
Fig. XII		PuBe 1" Poly	
Fig. XIII		PuBe 2" Poly	
		PuBe 4" Poly	

Figs. 2, 3, 4, and 5 show some results from these calibration measurements.

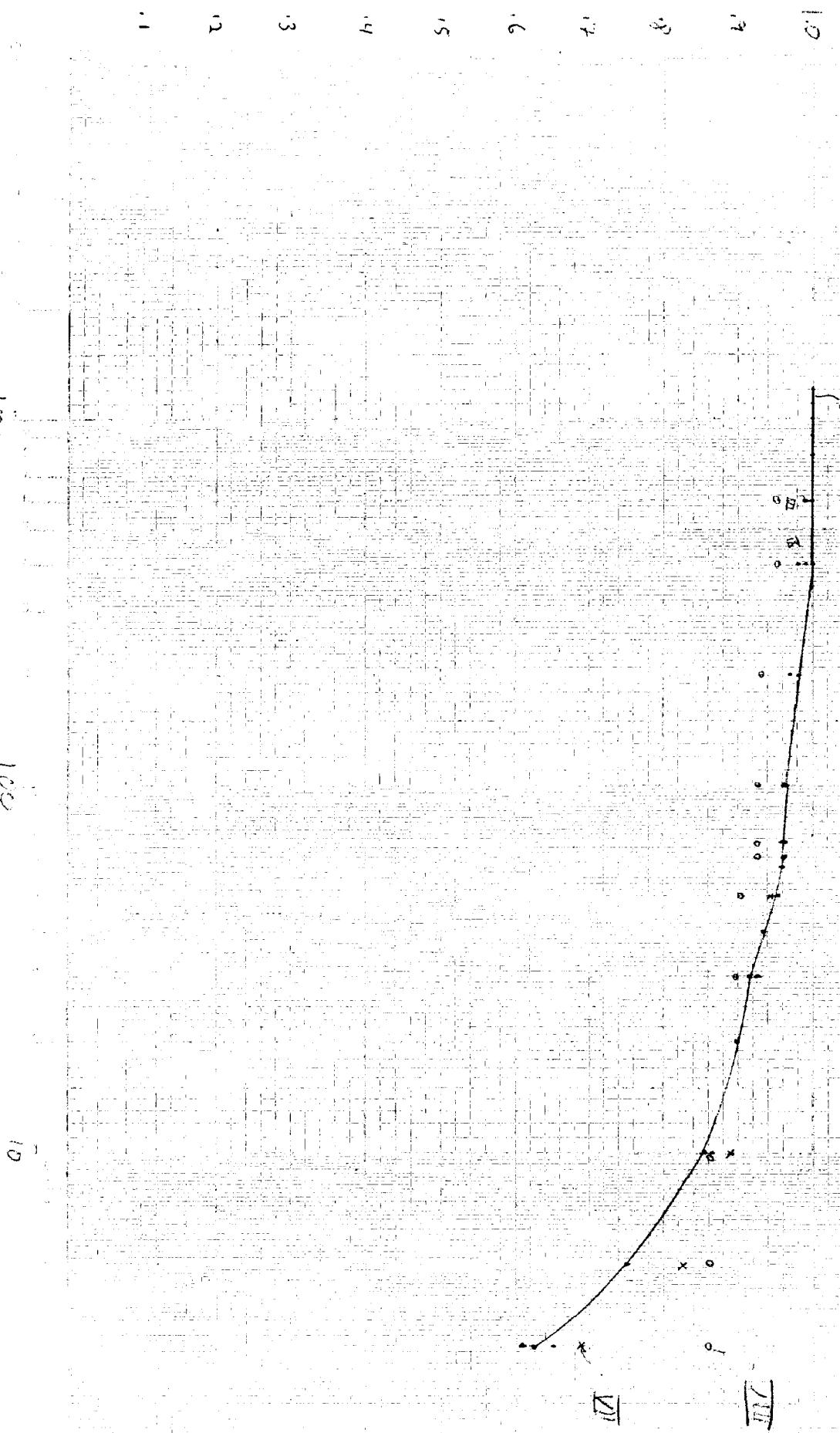
TABLE II

<u>LOCATION</u>	<u>DESCRIPTION</u>	<u>QE</u>	<u>PLATEAU CURVE</u>
Batavia Road of Neutrino Berm	Thick earth shield muons + hadron cascade (300 GeV/c triplet train run)	$3.5 \pm 1.$	
Enclosure 100 Roll up door.	Thick concrete shield outside a beam loss point (300 GeV/c)	5.3 ± 1.3	
Muon Lab	Muons (200GeV/c)	$0.9 \pm .3$	Fig. 6
Meson Detector Building	M2 Beam line above E8 Magnet (300 GeV/c)	$5.5 \pm 3.$	Fig. 7
Emergency exit in Enclosure 100	Measurements in a Labyrinth near a beam loss point (400 GeV/c)	$6.5 \pm 2.$	Fig. 6
PRAD (Proton Radiography Facility)	200 MeV Protons incident on a water tank	10^{+3}_{-1}	Fig. 8
PRAD	Same as above but with poly shielding in place	5.1^{+1}_{-1}	Fig. 9
Cancer Therapy Facility	Air Door Shielding Studies scattered neutrons from 65 MeV protons on Be	5.5	Fig. 10



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$\frac{I}{I_{sat}}$



VOLTAGE

FIGURE 3

VOLTAGE

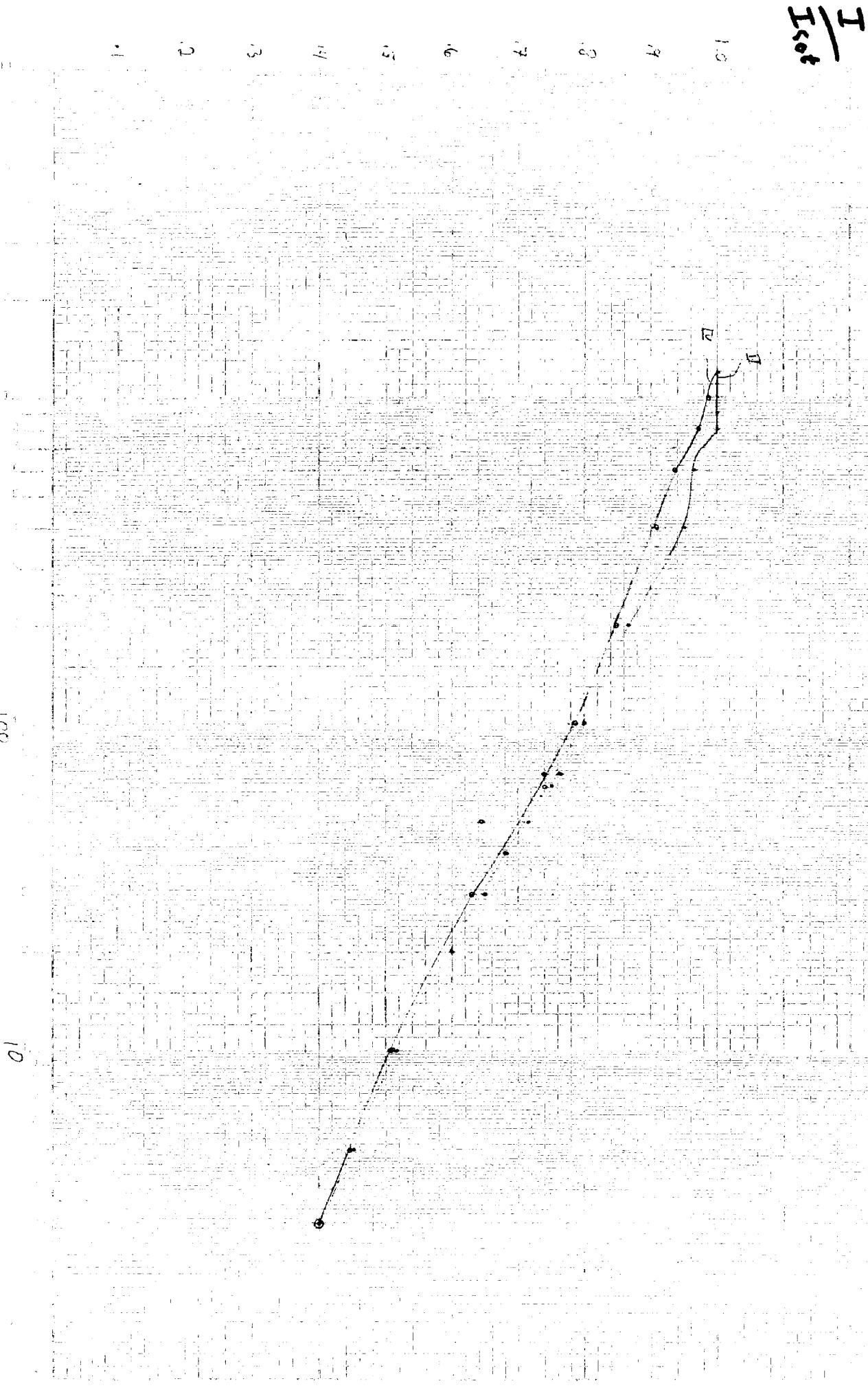
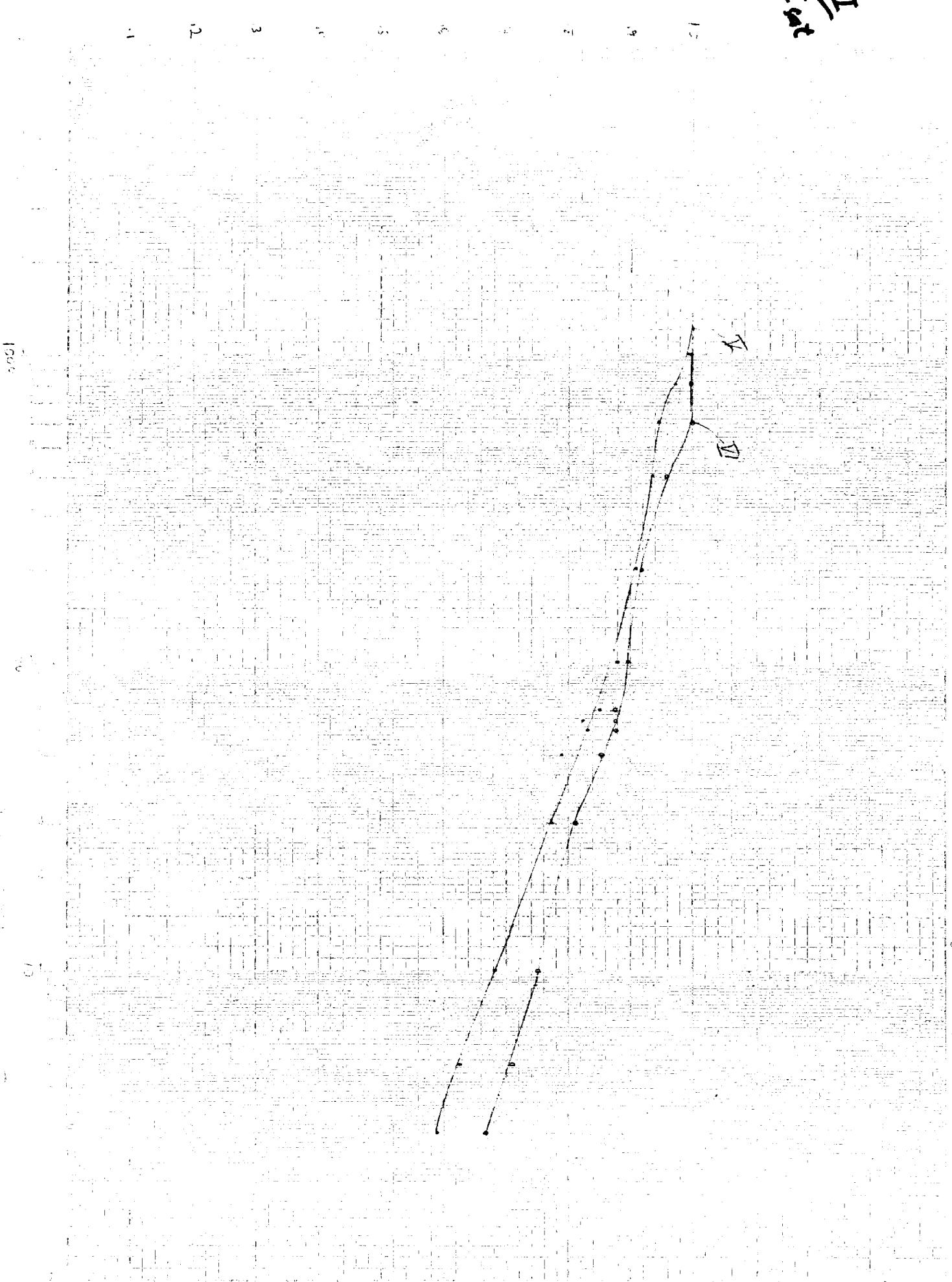


FIGURE 4

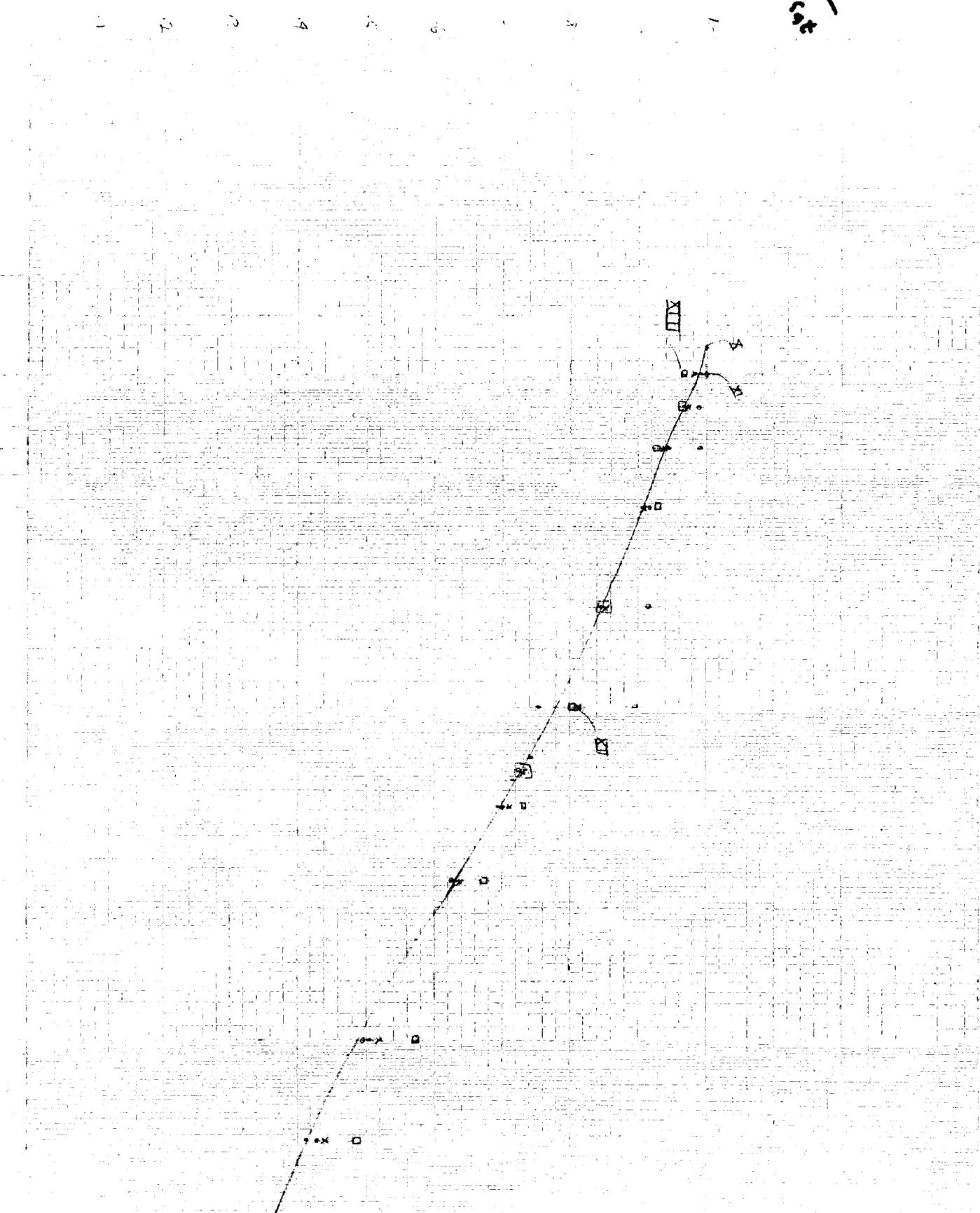
VOLTAGE



$\frac{I}{I_{\text{sat}}}$

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VOLTAGE



X RAY • CS CROWN + 2100 " (2nd 100) (POSITION #2)

Figure 6

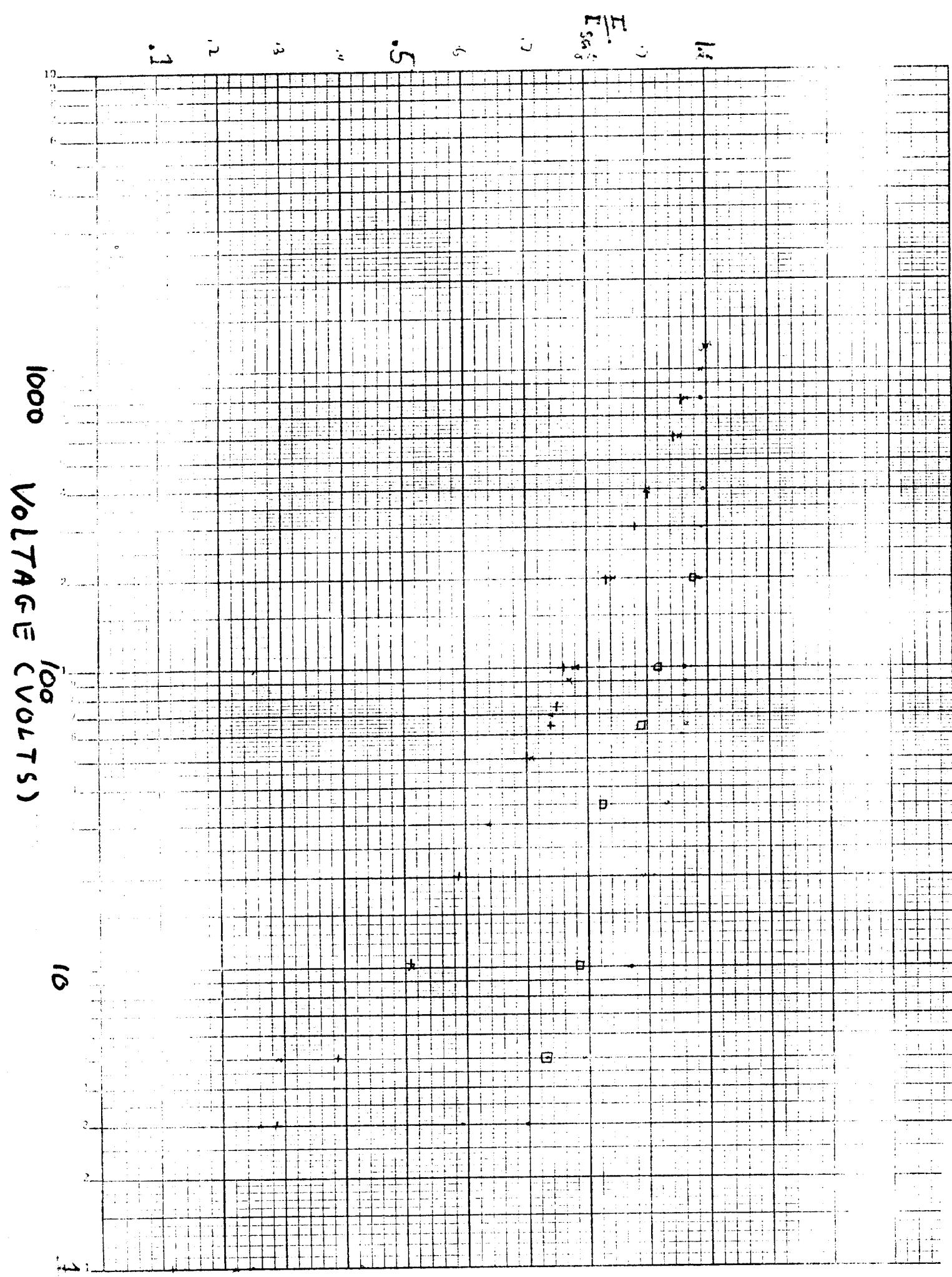
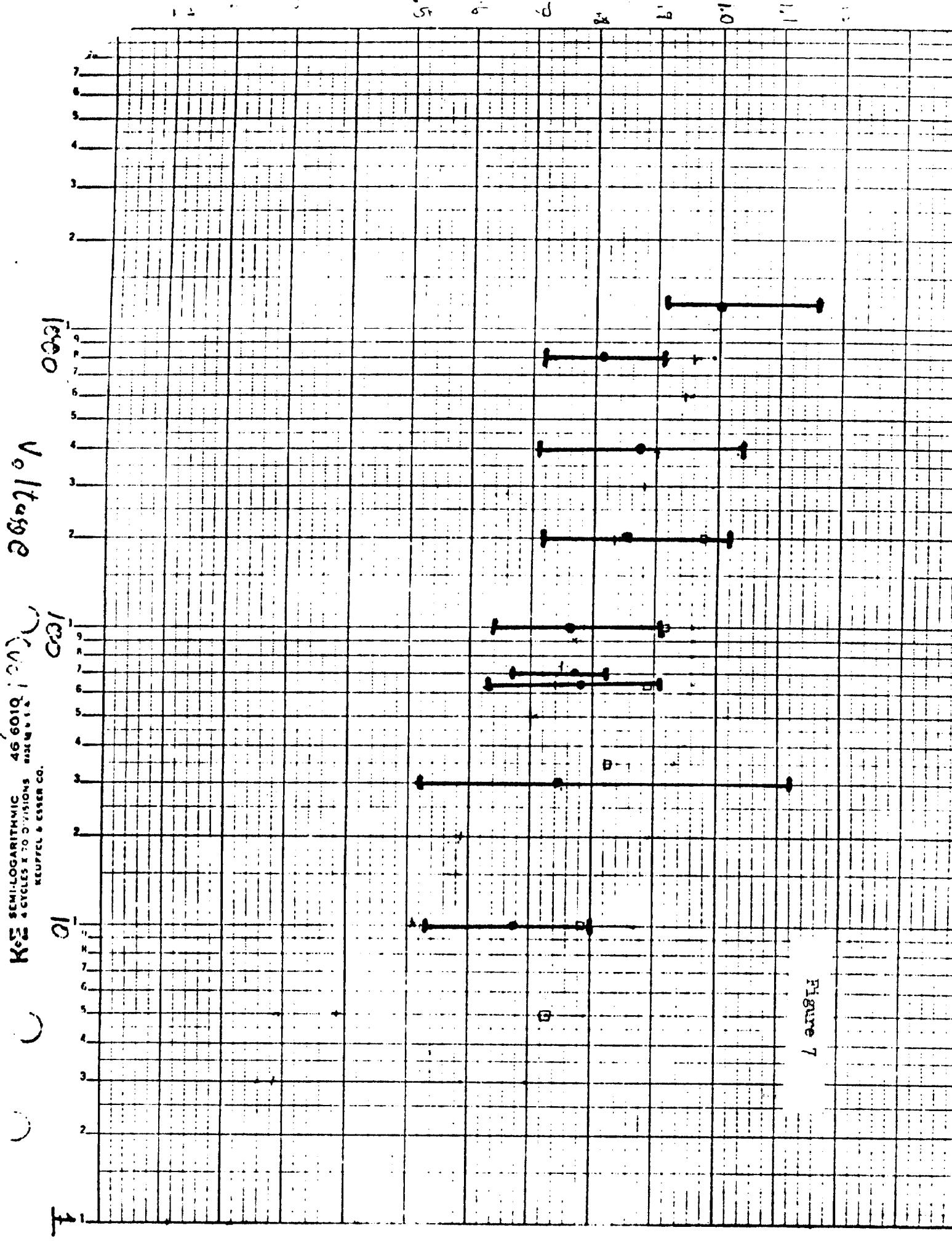
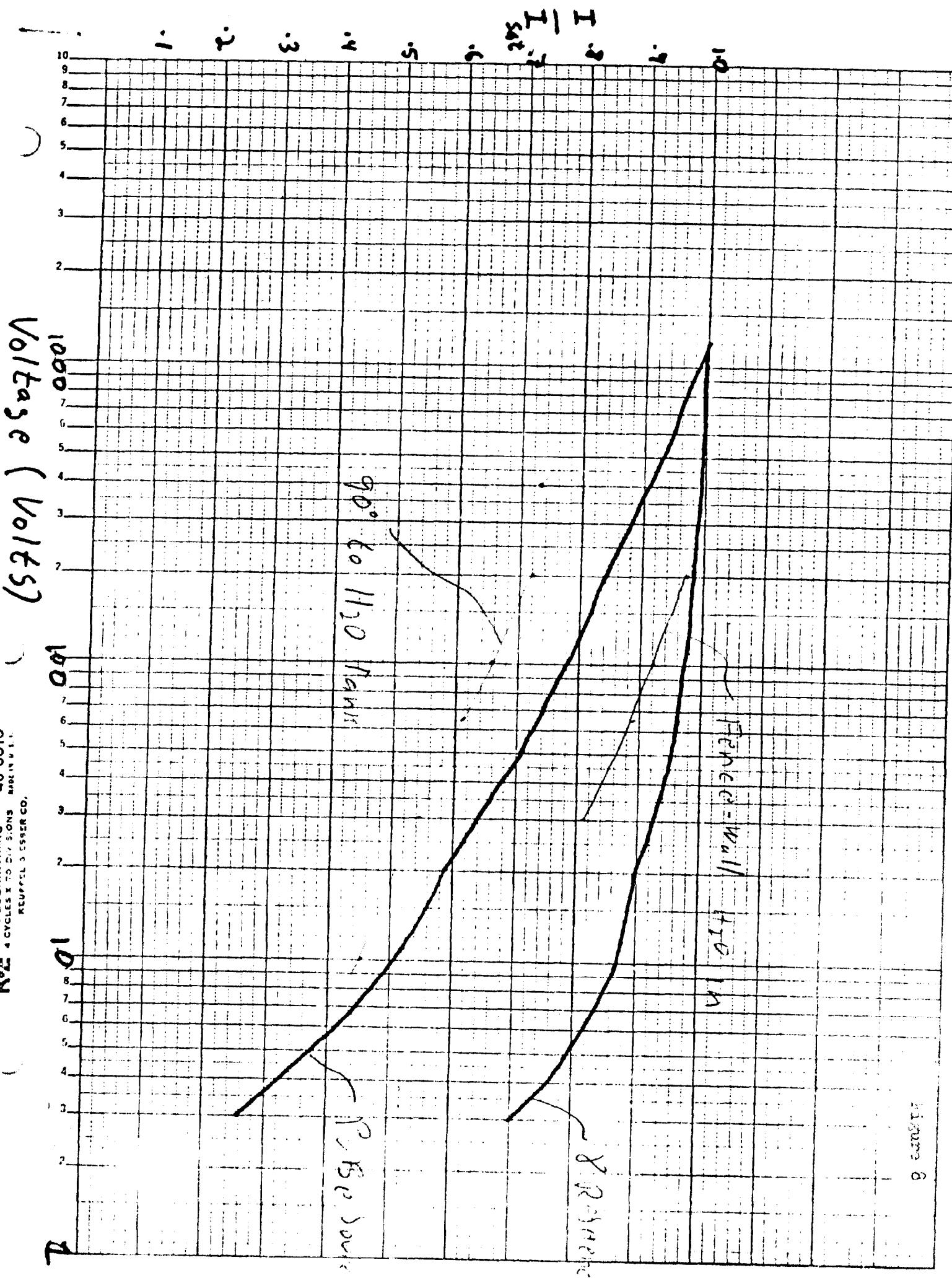


Figure 7



KoE SEMI-LOGARITHMIC 46 6010
4 CYCLES X 70 DAYS SONS MARTINSON,
REUFEL & ESSER CO.



K-E SEMI-LOGARITHMIC 46 6010
K-E 4 CYCLES X 70 DIVISIONS MADE IN U.S.
KEUFFEL & ESSER CO.

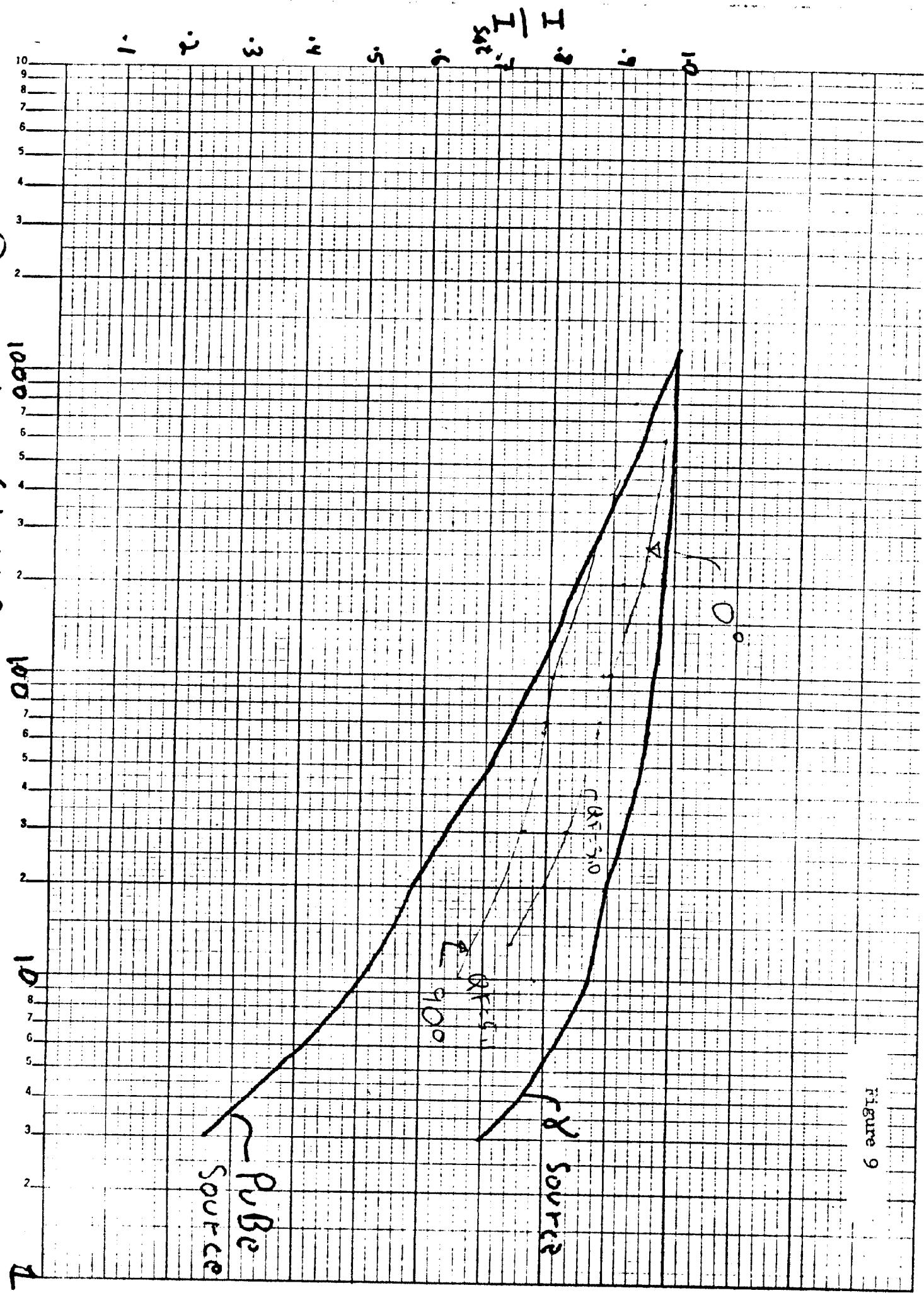
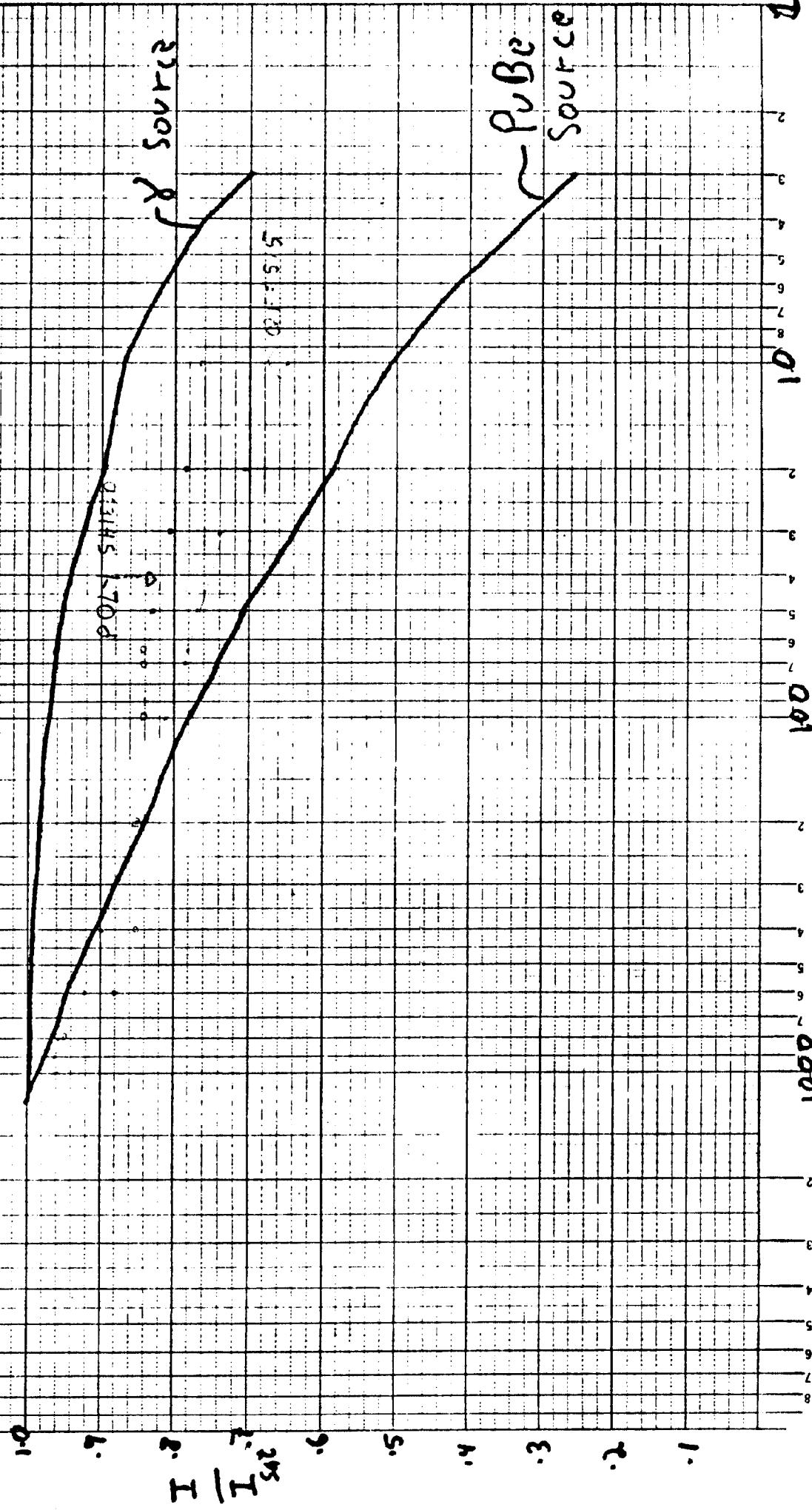


Figure 9

K_E SEMI-LOGARITHMIC
4 CYCLES X 10 DIVISIONS MADE IN U.S.A.
REUFFEL & ESSER CO.

(52101) 0907101

0.4 amperes



OPERATIONAL PROCEDURE FOR REM-2 CHAMBER

A. Equipment Needed

1. Chamber
2. Variable H. V. Supply
3. Keithly Electrometer (602)
4. Cables:
 - a. 2RG-58 - Reynolds one end, polish on the other
 - b. Essex 21-537 Low noise - BNC both ends.

A. Set Up Procedure

1. Connect 21-537 cable to chamber and Keithly
2. Connect 2RG-58 to H. V. Supply and chamber (both cables)
3. Let settle for five (5) minutes

C. Check Out

1. Put in known field. Current out $\approx 1 \times 10^{-9}$ A/R/HR @ -1200 volts. IE. 100 mR/hr field $\approx 1 \times 10^{-10}$ A.

D. Use

1. When taking readings field must be stable or total dose during reading must be known by using another instrument as a monitor such as an HPI-1030.
2. Take readings at the following voltages:

a. -1200	g. - 400	m. - 40
b. -1100	h. - 200	n. - 30
c. -1000	i. - 100	o. - 20
d. - 900	j. - 70	p. - 10
e. - 800	k. - 65	q. - 5
f. - 600	l. - 50	u. - 3

E. Results

1. Resulting curve after normalizing to current at -1200V must resemble the curves on the following page. Note: If dose varies the current must be scaled by the ratio:

$$\frac{\text{Dose } (v = 1200)}{\text{Dose } (v = v)}$$

2. QF is determined by dividing the current at -1200 volts by the current at -65 volts, subtracting that ratio from 1 (one) and multiplying by 25.

$$QF = 25 \left[1 - \frac{I_v = -65 \text{ volts}}{I_v = -1200 \text{ volts}} \right]$$